BIG HOLE RIVER ARCTIC GRAYLING RESTORATION PROJECT

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BY

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Fluvial Arctic Grayling Workgroup

and

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ABSTRACT

The Big Hole River Arctic grayling recovery project began in 1991 in an effort to reverse recent declines in grayling abundance in the Big Hole River. Research in 1992 included monitoring and mitigating water related limiting factors, monitoring population abundance and status, assessing the effects of angling on the population, maintenance of a reserve stock of grayling, conducting experimental plants of grayling, and a public information program. Drought continued in 1992, with extremely low flows measured in May and August - September. Low flows impacted recruitment in the McDowell and Wisdom West Channel, and may have affected adult grayling survival through the summer and fall. Water temperatures peaked at 81 F, which exceeds Critical Thermal Maximum for adult grayling. Mean daily temperatures at three downstream thermograph stations neared 70 F. Efforts to develop water conservation strategies were pursued with local water-users.

The Age I+ grayling population density was estimated at 31 per mile, approximately equivalent to the past four years. It appears that the population has stabilized after declines between 1983 and 1985. The extended drought appears to have limited all resident fish species in the upper Big Hole basin.

Effects of angling on the population were investigated through a voluntary creel census, angler counts, a hooking mortality study, and an analysis of the frequency of hooking wounds on grayling. Results indicate that the majority of fishing pressure on the Big Hole River was exerted in the lower reaches where grayling are in low densities. The reaches where grayling are most abundant received 19% of total angling pressure. The occurrence of hooking wounds was also lowest in the reach where grayling are most abundant. Hooking mortality results are as yet inconclusive, and the study will be continued. It appears that catch-and-release-only regulations are sufficient to protect the population, and angling is probably not a major limiting factor.

The brood reserve program began in 1988, with gametes of wild Big Hole grayling collected annually to add to the reserve. Gametes from a total of 28 founding parents have been collected, and reared at the USFWS Fish Technology Center. By 1995, each year class will be crossed with each other to form a reserve stock with genetic variability equivalent to the wild stock. The stock will be used to supplement the wild population, if necessary, and to provide a source of fluvial grayling for reintroductions into other streams. Reserve grayling were planted into the Gallatin River and the Big Hole River to develop techniques and observe survivability and movements. Preliminary results indicate that the planted grayling survived well, and dispersed over long distances.

INTRODUCTION

The Arctic grayling (Thymallus arcticus) of the Big Hole River drainage may be the last remnant of strictly fluvial, or stream-dwelling grayling in the lower 48 United States. While fluvial grayling are native to the upper Missouri River drainage, only the Big Hole and Madison Rivers, and Red Rocks Lakes still support indigenous grayling populations (Vincent 1962, Kaya 1990). Madison grayling primarily reside in Ennis Lake, and therefore are not considered strictly fluvial (Byorth and Shepard 1990).

During the 1980's, the Big Hole grayling population declined from 111 Age I+ per mile in 1983 to a low of 27 per mile in 1989 (Montana Department of Fish, Wildlife, and Parks (MDFWP) Files). In response to the decline, an inter-agency committee was formed in 1987 to direct research identifying limiting factors and develop a restoration plan (Kaya 1990, Byorth 1991). The committee, the Fluvial Arctic Grayling Workgroup, initiated the Big Hole River Arctic Grayling Restoration Program in 1991. Primary objectives of the Program as outlined by Byorth (1992a) are:

I. Define ecological factors limiting the abundance of Arctic grayling in the Big Hole River drainage,

II. Monitor population trends, enhance abundance, and expand the range of fluvial Arctic grayling, and

III. Educate the general public to increase awareness and support for grayling restoration.

Research in 1992 was directed by the following specific objectives:

A. Identify and mitigate water-related factors affecting Big Hole grayling,

B. Monitor the grayling population through population estimates and surveys,

C. Assess the potential effects of angling on Big Hole grayling,

D. Maintain a reserve stock of Big Hole grayling and conduct test plants of grayling into suitable habitats, and

E. Develop a public information program to raise interest and support for Big Hole River Arctic grayling recovery.

Information reported herein was collected between March and October of 1992. Research on movements of grayling in the Big Hole drainage is underway and will be reported upon completion of the study.

METHODS AND STUDY AREAS

Discharge and Water Temperatures

Discharge and water temperature were recorded at the U.S. Geological Survey (USGS) gage located at Wisdom (Figure 1). Data used in analyses were provided by USGS and are preliminary. Additional thermographs were placed at 4 locations along the Big Hole River (Figure 1). Thermograph stations consisted of Omnidata Datapods (Model DP212, Omnidata International Inc., Logan, Utah) placed in a sealed metal box and buried in a 5 gallon plastic bucket in the streambank. Temperature probes were threaded through garden hose into the stream and fixed to the substrate with cobbles. Water temperature was recorded at 120 min intervals on memory chips which were replaced approximately every 85 days. Data were downloaded into dBase III+ files (Ashton-Tate) and analyzed using dBase programs.

An effort was made to elicit cooperation with Big Hole basin water-users to keep the river flowing during the record dry year. A meeting was held in Wisdom to explain the status of the grayling population and the need to maintain flows to protect it. A letter requesting assistance in maintaining a live flow followed the meeting.

Population Surveys

Electrofishing was used to sample grayling in the Big Hole River, tributaries, and irrigation canals. We used a mobile anode system consisting of a 4,000 watt AC generator and a Leech or Coffelt Mark XXII rectifying unit to convert output current to DC. Equipment was mounted on either a fiberglass drift boat or Coleman Crawdad and operated downstream. Grayling were netted and retained in a live well for processing. They were anesthetized in an ethyl 4-aminobenzoate bath, measured to the nearest 0.1 inches in total length, weighed to the nearest 0.01 lb. We collected scale samples, notched a fin, noted presence of hooking wounds, and tagged each grayling with an individually numbered and color-coded VI tag (visible implant, Northwest Marine Technology, Inc.). They were allowed to recover and released. Population estimates were derived based on mark-recapture ratios using the Chapman Modification of the Peterson mark/recapture model (Chapman 1951). Confidence intervals (CI) are reported at $\alpha=0.05$.

We conducted spawning surveys in three sections: McDowell, Wisdom, and North Fork (Figure 1). One or two crews electrofished the sections from April 14 to April 27, 1992. Spawning condition was monitored and gametes were collected during the peak of spawning for addition to the brood reserve stocks. Sapmles of fecal material and ovarian fluid were taken for disease analysis.

We surveyed the McDowell and Wisdom sections and attempted to estimate abundance in June of 1992. However, extremely low

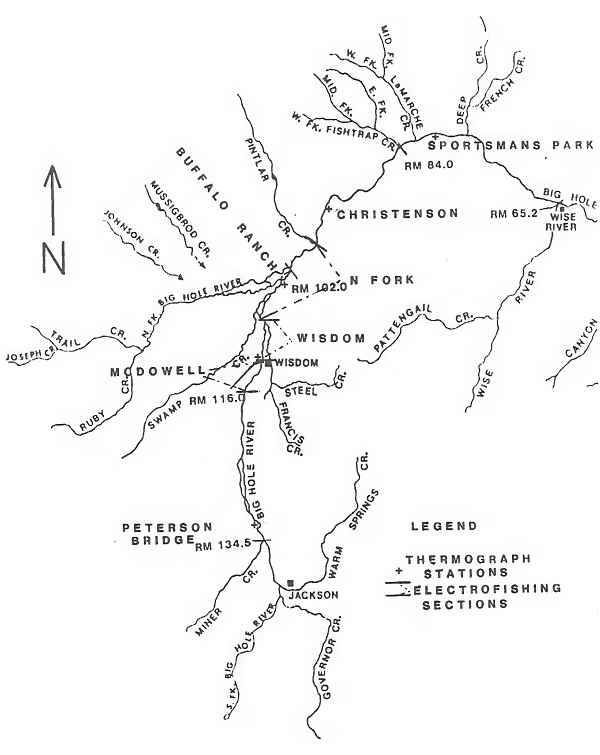


Figure 1. Map of the Big Hole River electrofishing survey sections and thermograph stations, 1992.

flows in the McDowell and Wisdom West channels prevented completion of recapture runs. We completed the mark/recapture experiment in the Wisdom East (Steel Creek) channel on June 12.

To determine mid-summer usage of the Big Hole River by grayling, we electrofished the 12 miles of river upstream of the McDowell section on July 15, 16, and 17, 1992. We conducted a survey of young-of-the-year (YOY) grayling in the Spokane and Double Fork ditches, and in Steel and Swamp Creeks August 17 and 18, 1992.

Fall population estimates were derived for the McDowell, and Wisdom sections. We marked grayling, brook trout (Salvelinus fontinalis), and rainbow trout (Oncorhyncus mykiss) September 1, 2, and 3, and recaptured them on September 16, 17, and 18, 1992. An additional 38 miles of the Big Hole River between the Wisdom section and Divide were surveyed for grayling in September and October, but due to low flows a large-scale population estimate was not feasible. A section of Deep Creek was surveyed as well.

Affects of Angling

Creel Census

We initiated a creel census in the Big Hole River to determine the potential impacts of angling on the grayling population. We defined four river reaches: (A) Jackson to Squaw Bridge, (B) Squaw Bridge to Dickie Bridge, (C) Dickie Bridge to Divide Bridge, and (D) Divide Bridge to Brown's Bridge (Figure 2). We selected the reaches based on availability of fishing access, and the relative densities of grayling and other species.

A voluntary creel card system and angler counts were used to determine angling pressure and catch rates. Fourteen creel census stations were established at key access points along the Big Hole River (Figure 2). Stations consisted of a map outlining river reaches and instructions, and a box containing creel census cards, return envelopes, and a return slot. Creel cards instructed anglers to indicate which reaches they fished within, their catch per species in each reach, and the time they spent fishing in each reach (Figure 3). Creel cards contained additional questions related to tackle and methods employed. Creel stations were operated from May 15 to November 4, 1992.

Angler counts were used to estimate fishing pressure. Nineteen count dates were selected between June 15 and October 18, 1992 using random numbers generated with Statgraphics (STSC Inc.). The census period was divided into three strata, each spanning 42 days: June 15 - July 26, July 27 - September 6, and September 7 - October 18.

Two counts were conducted on each count date, morning and afternoon. The starting point for each count was either Jackson (the head of Reach A) or Brown's Bridge (the end of Reach D). The starting point for the morning count was selected at random (Statgraphics), and the afternoon count began at the alternate

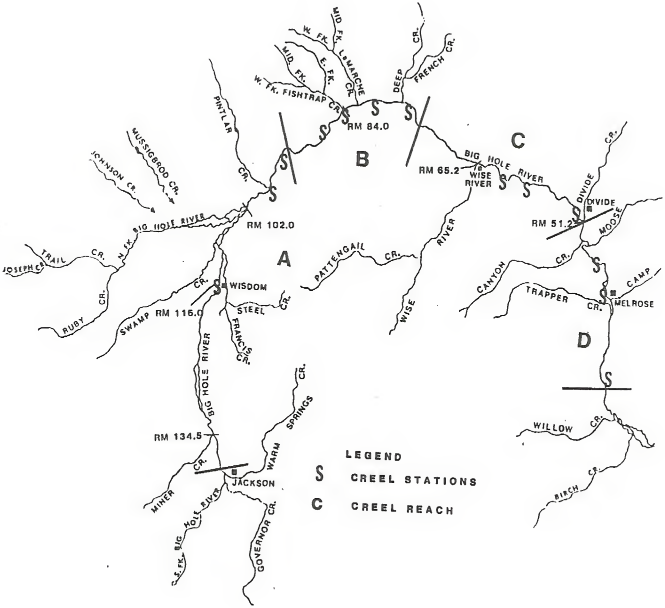
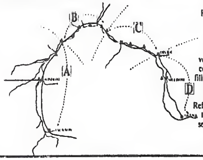


Figure 2. Map of Big Hole River creel census sections and locations of creel stations.

Arctic Grayling Recovery Program

ANGLERS CREEL CENSUS SECTIONS



In conjuction with the Big Hole Grayling Recovery Project, MDFWP is conducting a voluntary creel census. Please fill out this creel card for each day you fish. Refer to the map to identify the section of river you fished.

Please fill in the table with the number of each fish species that you caught in each section, and the number of hours you fished in each section. Return to the "Completed Card" box or mail in the provided envelope.

If you are interested in learning more about the recovery project, or would like to contribute to the Big Hole River Arctic Grayling Recovery Fund, please use the envelope to mail your donation. ***Thank You!***

☐ *Yes! I would like more information on the Arctic Grayling Recovery Project*

☐ *Enclosed is a contribution $*

ANGLERS: **Please answer each question and return this card to the box, or mail. Thanks for your cooperation!**

1. Which section(s) did you fish today* A B C D
2. Please fill in table with the number of each fish species you caught (and kept) and hours you fished per section:*

SECTION		GRAYLING	BROOK TROUT	BROWN TROUT	RAINBOW TROUT	WHITEFISH	HOURS FISHED
	A		( )	( )	( )	( )	
	B		( )	( )	( )	( )	
	C		( )	( )	( )	( )	
	D		( )	( )	( )	( )	

3. Are you done fishing for today? Yes No
4. Did you fish specifically for grayling? Yes No
5. Which tackle did you use? Bait Lures Flies *Refer to Map on Sign
6. Did you fish from: Shore Boat
7. Name: Address:
   City: State: Zip: Date:

Figure 3. Example of creel census card used in the Big Hole River creel census, 1992.

site. Starting times for the morning and afternoon counts were chosen at random using Statgraphics. Potential start times were 6:00, 7:00, 8:00, or 9:00 am for the morning count, and 1:00, 2:00, 3:00, or 4:00 pm for the afternoon count. Count dates, starting point and time are outlined in Appendix Table A1.

The procedure used in each count is summarized in Appendix Table A2. Clerks proceeded from the starting point and counted anglers, vehicles, boats, boat anglers, and boat trailers at access points and along the river. Creel clerks interviewed anglers as to the number in their party, which was used to derive mean number of anglers per car (1.86) and per boat (2.47) to correct for unoccupied vehicles and boat trailers. Clerks were instructed to complete counts within each reach within an hour, which is considered an instantaneous count (Neuhold and Lu 1957).

We entered data from the creel cards and counts into dBase III+ or dBase IV files. We analyzed creel census data with MDFWP's creel census program (McFarland and Roche 1987). The number of anglers in a count period was corrected for unoccupied vehicles and boat trailers, (i.e. anglers not in view). To derive pressure estimates we calculated the total number of shore and boat anglers in a given count as follows:

$$T_s = \text{greater of } A_s \text{ or } (1.86)V$$

and

$$T_b = \text{greater of } A_b \text{ or (greater of } [N_t \text{ or } N_b(2.47)]$$

Where:

T_s = Total shore anglers
T_b = Total boat anglers
V = Vehicles counted
A_s = Shore anglers counted
A_b = Boat anglers counted
N_t = Trailers counted
N_b = Boats counted

We derived pressure estimates from corrected angler counts and average trip length given on creel cards. Catch per effort statistics were derived from creel cards as well, and compared using pairwise t-tests, with the level of significance held at $\alpha=0.05$.

Hooking Wound Frequency

Since 1983, MDFWP fisheries crews have noted presence or absence of hooking wounds on each fish that they handled. We tabulated the frequency of hooking wounds on grayling from 1984 to 1992, by sampling section and creel census stream reach. Frequency was calculated as percent of fish in the sample with scarred or deformed jaws, or the presence of a hook or lure in the oral cavity.

Hooking Mortality

Arctic grayling have been managed under catch-and-release-only regulations in the Big Hole River drainage since 1988. Stress and injury due to hooking by anglers may cause mortality in spite of catch-and-release regulations (Wydoski 1977). To assess the potential effect of angling on the Big Hole grayling, we initiated a study to determine mortality rates due to hooking.

Grayling were captured with hook-and-line, played quickly, and netted. We anesthetized, weighed, measured, and VI tagged each grayling. We also noted its sex, terminal tackle on which it was caught (flies, bait, lures and barbed or barbless hooks), time and water temperature at capture, and hooking location. Hooking locations were defined as modified from Mongillo (1984 in Loftus et al. 1988). Each grayling was placed in a 48"x48"x60" live well placed in the river and its condition was noted.

We held the grayling in the live car for at least 48 h. Based on pertinent literature, 48 h should have been sufficient to observe short-term mortality while preventing undue mortality through holding stress. According to Falk (1974), the majority of grayling hooking mortality occurred in the first 24 h after capture. However, Dotson (1982) found the majority of mortality in Yellowstone cutthroat trout (Oncorhyncus clarki bouveri) occurred within 72 hr. Marnell et al. (1970) found that most mortally wounded Yellowstone cutthroat trout died immediately, although they recorded mortality up to 6 days after capture. Schill et al. (1986) determined that holding stress may contribute to long-term mortality. It has been the author's observation that grayling do not tolerate being held more than a few days. We noted the status of each grayling at the end of the 48 h period and released them in the vicinity of their capture.

Brood Reserve and Experimental Reintroductions

Big Hole River

In 1988, a brood reserve program was established by collecting gametes from spawning Big Hole grayling. The intent of the program was to provide a genetic reserve of Big Hole grayling to guard against extirpation of the unique fluvial stock and to provide a source for future enhancement and reintroductions. Leary (1991) developed the plan to ensure that the integrity of the wild gene pool was maintained in the reserve stock.

During spring spawning surveys of the McDowell, Wisdom, and North Fork sections, we collected gametes to add to the reserve stock. Gravid female grayling were captured by electrofishing, and retained until 2 ripe males were captured per female. Personnel from the U.S. Fish and Wildlife Service (USFWS) Fish Technology Center (FTC, Bozeman, Mt.), Montana State University (MSU), and MDFWP stripped the females eggs into a vial, and collected milt from 2 males using an aspirator, allowing both males' gametes to mix. We added milt to the eggs with a small volume of water. After several minutes we rinsed the eggs with water to remove excess milt. The grayling were allowed to recover and released. Fertilized eggs were transported in separate vials to the FTC in coolers.

Axolotl Lakes

A reserve stock was established in 1988 in a barren lake in the Axolotl Lake chain of the Gravelly Range (Figure 4). The lake lies at an elevation of 6860 ft and covers approximately 6.4 surface acres. Approximately 2,800 YOY fry were planted, which were derived from wild Big Hole grayling spawned in the spring of 1988.

The Axolotl brood was Age IV in 1992, nearing their maximum life span. To maintain a representation of the 1988 year class in the brood reserve, we collected gametes in May 1992. We captured grayling using 2 fyke nets set at different locations in the lake. Net leads were run from shallows and fykes were set at approximately 12 ft deep. We operated the nets overnight. Grayling were removed from the fykes and sorted by sex. Each sex was retained in 48"x48"x60" live cars placed in the lake. A sample from each catch was measured, weighed, and spawning condition was noted. Grayling from later catches were marked with a fin clip for population estimates.

Personnel from USFWS Ennis National Fish Hatchery (ENFH) spawned grayling according to methods described above. Fertilized eggs were transported to the FTC for rearing. A sample of grayling was taken for disease analysis and the rest were released.

Water temperatures were monitored with Omnidata DP212 thermographs. Thermographs were placed to record air temperature, inlet water temperature, and mid-lake and outlet water temperatures. A trap was also placed in the inlet stream to catch grayling attempting to spawn in the stream.

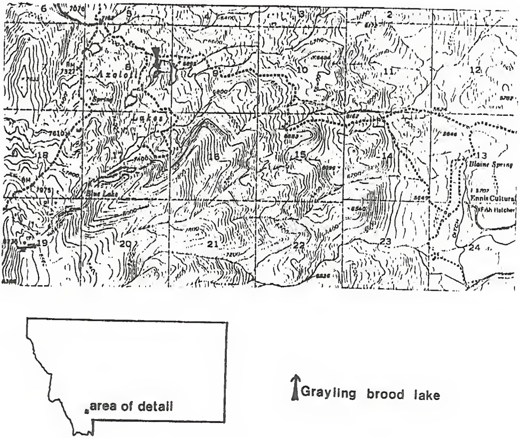


Figure 4. Map of Axolotl Lakes area, Madison County, Montana.

Gallatin River Experimental Reintroduction

An objective of the Big Hole Grayling Restoration plan is to expand the range of fluvial grayling by reintroducing them into suitable streams within their native range (Fluvial Arctic Grayling Workgroup 1989). The brood reserve would serve this purpose and may also be used to enhance the wild Big Hole River grayling population if necessary. In order to meet these objectives, planting techniques must first be developed.

The Gallatin River was selected for an experimental reintroduction of grayling because of its potentially suitable habitat and low densities of other salmonids. Furthermore, no graying were present that could be affected genetically. An Environmental Assessment was prepared in accordance with the Montana Environmental Policy Act (Byorth 1992b).

On July 1, 1992 approximately 5,400 yearling grayling averaging 5.9 (range 4 to 8) inches long were planted by USFWS and MDFWP personnel. The grayling originated from wild Big Hole grayling spawned in 1991 and reared at FTC. One week prior to planting, each fish was marked with a VI tag and a coded wire tag implanted in its rostrum. The fish were divided into 3 equal lots and transported in a tank truck to the planting site. One lot was planted at each of three sites all within a 1.5 mile reach of the Gallatin River immediately downstream of Yellowstone National Park (YNP) (Figure 5) (Fredenberg, MDFWP Files).

To monitor movements, we electrofished four sections; Black Butte in YNP, Snowflake Springs at the plant site, Big Sky, and Axtell (Figure 5). We used the same electrofishing methods as outlined above. In addition, we posted signs along the Gallatin River alerting anglers to the plant and requesting that they report capture sites and dates. A news release was also distributed to elicit information. As anglers reported catching grayling, information on capture date, location (nearest highway mile marker), and the number of grayling captured was logged and mapped. Highway mile markers were converted to river miles (distance from mouth of Gallatin River) according to the River Mile Index (Mt. Department of Natural Resources and Conservation 1979).

Big Hole River Experimental Plant

To evaluate the behavior of brood grayling when planted into the Big Hole River, we planted 214 4 to 8 inch yearling grayling on July 2, 1992. Each grayling was marked with a VI tag, and/or a coded wire tag. The grayling were transported from FTC in an oxygenated tank to the planting site at the confluence of Sawlog Creek and the Big Hole River. We adjusted tank water temperature (48 F) with river water to allow the grayling to acclimate to river temperature (56 F). We divided the fish into two approximately equal lots, and planted one lot in each of two consecutive pools near the mouth of Sawlog Creek. We monitored movements during electrofishing surveys described above.

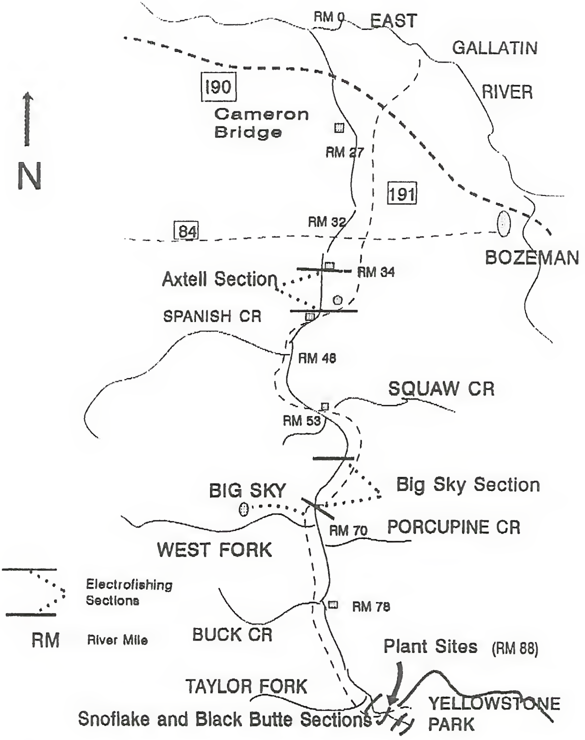


Figure 5. Map of the Gallatin River, Montana, showing sites of grayling plants and electrofishing sections.

Public Relations

To increase awareness of the situation confronting the Big Hole grayling, we presented a program to 10 groups throughout southwestern Montana. The organizations included local Trout Unlimited chapters in Hamilton, Missoula, Butte, Bozeman, and Livingston, an angling group in Gardiner, the Fish and Wildlife Forum at MSU, Pintler Chapter of the Audubon Society, the Montana Riparian Association, and the Montana Stockgrowers Association.

In addition, an article was published in Montana Outdoors (Byorth 1992c). Other popular articles concerning the Big Hole grayling were published in Fly Fisherman Magazine (Drake 1992), and in Trout (Behnke 1992, and Wuerthner 1992).

RESULTS

Discharge and Water Temperature

Discharge

The April through September hydrograph from the USGS gage at Wisdom illustrates extreme drought conditions in the Big Hole basin in 1992 (Figure 6). The instantaneous peak flow was 610 cfs on June 17, 1992, which was 65% lower than the peak of 1,080 cfs recorded in 1988, another year of record drought. In 1991, discharge peaked at 4,300 cfs. No major pulse of run-off flows occurred in 1992.

Several periods of extreme low flow were observed in 1992. On May 18, flows decreased from 20 to 6.7 cfs during the normal period of runoff. Just prior to this decline grayling fry should have emerged from the gravel, and the sudden flow reduction probably reduced rearing habitat and impeded recruitment. In response to earlier solicitations, local water-users decreased withdrawals which increased flows from a low of 3.3 cfs to 32 cfs by May 26. A second major flow reduction occurred between June 9 and 10, when discharge decreased from 15 to 7 cfs. June rains provided relief as flows increased to the peak flow on June 17. Rains continued until mid- to late-August when flows began to decrease to a low of 3.9 cfs on September 4. The lowest flow recorded in 1988 was 0 cfs in August, and in 1991 was 11 cfs on September 4 and 6.

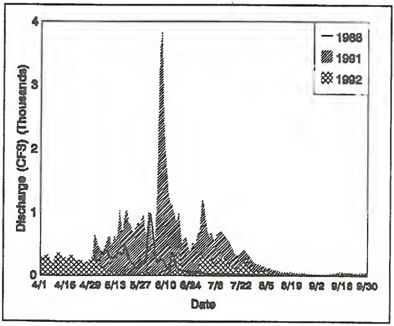


Figure 6. Big Hole River hydrograph measured at the USGS Wisdom gage, 1988, 1991, and 1992.

Water Temperatures

The maximum water temperature of 81 F was recorded at the Christiansen Station on August 14, 1992. However, the greatest mean daily temperature was recorded at Sportsman's Park on June 23. Maximum temperatures at all stations other than Christiansen's were recorded on June 23. Maximum daily and maximum mean daily temperature recorded at each station are reported in Table 1.

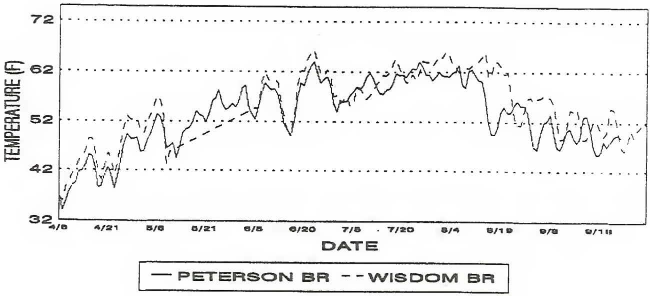
Table 1. Maximum daily (T_{max}) and maximum mean daily temperatures (Mean T_{max}) (F) recorded at Big Hole River thermograph stations, 1992.

Station	T_{max}	Mean T_{max}
Peterson Bridge	71.6	64.0
Wisdom Bridge	75.9	66.4
Buffalo Ranch	77.0	69.1
Christiansen	81.5	68.5
Sportman's Park	79.7	70.6

The maximum temperature recorded at the Christiansen Station exceeded the Critical Thermal Maximum (CTM) reported by Feldmuth and Eriksen (1978) of 80.4 F for adult grayling, but not for YOY grayling (83.6 F). The greatest mean daily temperatures recorded at the lower 3 stations approached the limit of suitability of 70 F for grayling reported by Hubert et al. (1985).

Water temperatures generally increased in a downstream gradient. Mean daily temperatures averaged 2.2 F (range: 0-4.3) greater at the Wisdom gage than at the Peterson Bridge station (Figure 7). Due to low flows, which exposed the thermograph probe, temperatures were not recorded at the Wisdom gage from May 10 to June 4 (Figure 7). Temperatures were similar between the Wisdom and Buffalo Ranch stations until early July, when temperatures were recorded as much as 10 F warmer at the Buffalo Ranch. As flows decreased in the mainstem, water temperatures at Wisdom periodically exceeded those at the Buffalo Ranch Station through August and September. The influence of Steel Creek, Swamp Creek, and accretions due to springs probably lowered temperatures between those stations.

Water temperatures remained fairly stable between the Buffalo Ranch and the Christiansen stations (Figure 8). Temperatures were roughly equivalent until early July when mean daily temperatures were recorded an average of 1.1 F (range: 0-2.4) higher at the Christiansen thermograph. By early August,



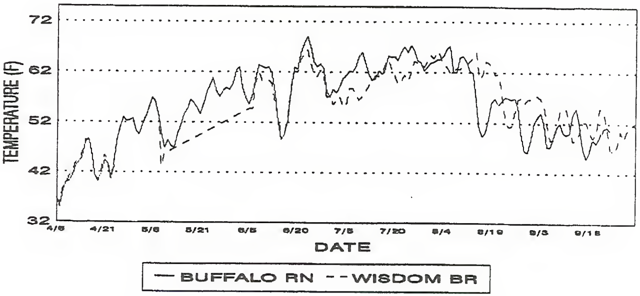


Figure 7. Mean daily water temperature (F) of the Big Hole River at the Peterson Bridge, Wisdom, and Buffalo Ranch thermograph stations, April through September, 1992.

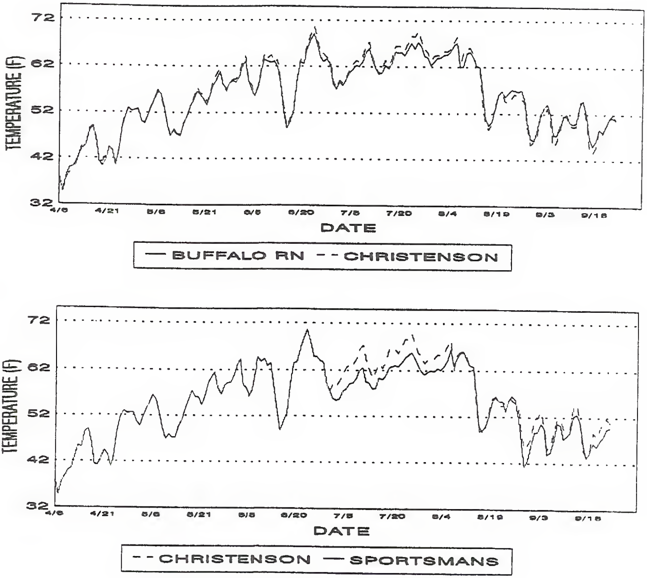


Figure 8. Mean daily water temperature (F) of the Big Hole River at the Buffalo Ranch, Christiansen, and Sportsmans Park thermograph stations.

temperatures returned to nearly equivalent between the Buffalo Ranch and Christiansen stations. A similar pattern existed between the Christiansen and Sportsman's Park stations. Mean daily temperatures were equivalent until July 1, when temperatures were an average of 3.4 F (range: 2.0-4.8) cooler at Sportsman's Park. By August 8 temperatures were again similar between stations. The influence of springs and several tributaries, and the shading effect of the canyon walls most likely contributed to the downstream cooling.

Population Monitoring

Spawning Population

The spawning run was surveyed in 1992 to characterize the spawning population and to collect gametes for the brood reserve. The spawning run peaked between April 21 and 24, 1992, at discharges between 231 and 254 cfs. Mean daily water temperatures ranged from 41.0 to 45.5 F during the peak.

We captured 204 Age II+ grayling, and estimated the total spawning population to be 886 (95% CI ± 172) based on mark:recapture ratios. The overall sex ratio of the spawning population was 1.65 males:female, but ranged from 0.5 to 0.8 males:female during the peak of the run. The spawning population was composed of 18% Age II, 51% Age III, and 31% Age IV+ grayling.

The proportion of Age III+ spawners (11 inches and longer) in the 1992 run was the highest recorded in the last 3 years (Figure 9). These age classes tend to be more efficient spawners, and hence should potentially provide better recruitment. As the the length-frequency distribution in Figure 9 indicates, Age III+ spawners were more abundant than in the two previous years. Age II spawners were less abundant than in those years, which indicates poor recruitment in 1990. The high number of 4 to 6 inch yearling grayling captured in 1990 are represented as Age III grayling in the 1992 spawning run.

June Population Surveys

A mark-recapture experiment was conducted in the McDowell and Wisdom sections in June of 1992. However, because of extreme low flows in the McDowell section and the Wisdom West channel, a population estimate was calculated only for the Wisdom East (Steel Creek) channel. An estimated 14.7 Age II+ grayling per mile remained in the channel post-spawning: 10.0/mi [95%CI ± 1.5] Age II (9.0 to 10.9 inches) and 4.7/mi [± 2.0] Age III+ (>11.0 inches). The length-frequency distribution indicates that a large number of 11.0+ inch grayling left the section after spawning (Figure 10). This supports earlier data suggesting that grayling congregate in the Wisdom area to spawn, and disperse throughout the basin thereafter (Shepard and Oswald 1989).

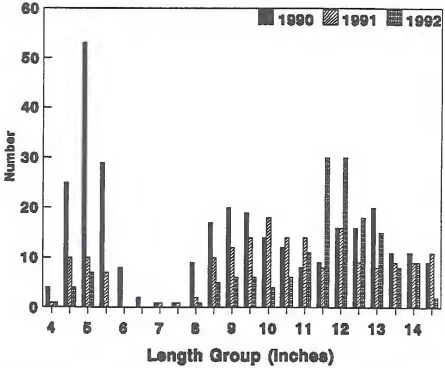


Figure 9. Length-frequency distribution of grayling captured in spawning surveys in the Big Hole River, April 1990-1992 (per 7 passes 1990 and 1991, and 9 passes in 1992).

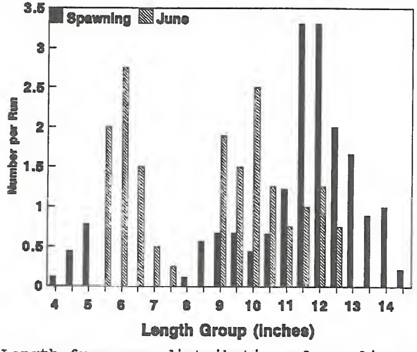


Figure 10. Length-frequency distribution of grayling captured per unit effort in spawning surveys versus June surveys of the Big Hole River, April and June 1992.

Summer Distribution

We surveyed the 12 miles of the Big Hole River above the McDowell section during July, 1992. Only 4 grayling were captured, while 636 brook trout and 27 rainbow trout were captured. Qualitatively, the habitat appears to be suitable for grayling.

Fall Surveys

Fall population estimates indicated that the Big Hole grayling population remains stable after declines in the mid-1980's. An estimate of 18.9/mi [± 10.4] Age I+ grayling was calculated by combining the McDowell and Wisdom sections (9.8 miles). However, this estimate is biased downward by low capture rates (M=3, C=4) and no recaptures (R=0) in the McDowell Section (4.87 mi). A less biased estimate of the Wisdom Section alone (4.89 mi) yields 31.4/mi [± 16.0] Age I+ grayling; 14.1/mi [± 8.5] 7.0 to 10.9 inches, and 17.3/mi [± 13.4] greater than 11.0 inches.

A similar situation existed in 1991 when the McDowell-Wisdom sections combined yielded an estimate of 34.3 [± 24.3] Age I+ grayling per mile. High capture rates (M=17, C=16), but no recaptures (R=0) biased the estimate upward in the 9.8 mile section. A more representative estimate would be 28.5 [± 18.4] Age I+ grayling per mile in the 4.89 mile Wisdom section. In 1991, however, the Wisdom section included only the East (Steel Creek) Channel due to a gravel plug that diverted flow from the West Channel. Estimates in the Wisdom Section indicate stable to slightly increasing grayling population from 1991 to 1992.

This illustrates the difficulty in accurately estimating the grayling population. Low numbers, extensive movements between mark and recaptures runs, and variability in flow conditions in the various sections contribute to variability in population estimates. This is discussed further below.

Length-frequency analysis of grayling captured in the McDowell-Wisdom sections indicated that Age I grayling (7.0 to 10.9 inches) were less abundant than in 1991 (Figure 11). Age II+ grayling (>11.0 inches) have increased over last year, especially in the Age III+ year classes. The poor Age I cohort is more apparent in the Three Pools survey sections (Figure 12). Three Pools length-frequency distributions for 1987-1991 are reviewed in Byorth (1991). The length-frequency for all grayling captured in all surveys again stresses the low numbers of yearling grayling in the population in 1992 (Figure 13). The Age II cohort appears to have increased over 1991, but scale analysis is required to separate Age II from Age III+ grayling. Age III+ cohorts increased in abundance, which was indicated in the spawning survey as well.

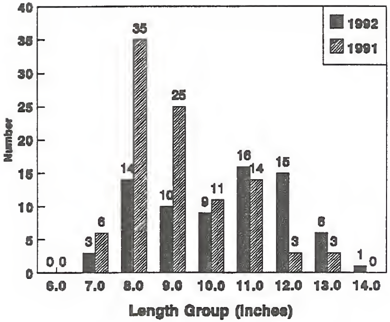


Figure 11. Length-frequency distribution of grayling captured in the McDowell and Wisdom survey sections of the Big Hole River, Fall, 1991 and 1992.

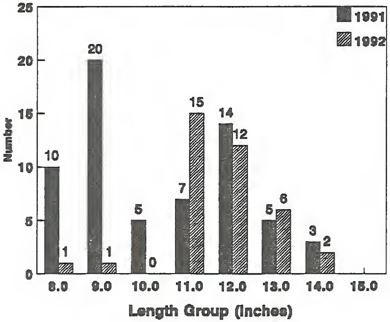


Figure 12. Length-frequency distribution of grayling captured in the Three Pools survey sections of the Big Hole River, Fall, 1991 and 1992.

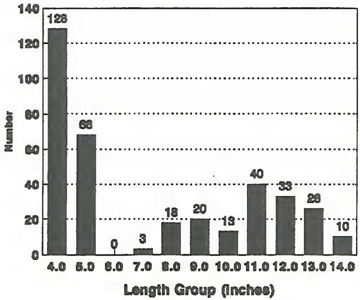


Figure 13. Length-frequency distribution of all grayling captured in Big Hole River electrofishing surveys, Fall, 1992.

<u>Young-of-the-Year</u>

We assessed recruitment of YOY grayling during summer and fall population surveys. In spite of low flows, spawning success was relatively high. Number of YOY grayling and capture locations are mapped in Figure 14. Mainstem Big Hole River spawning success was moderate in the McDowell Section and the Squaw Creek area with 42 YOY captured in each in 2 passes. In the McDowell Section the majority of YOY grayling were caught above the diversions. The reach in the vicinity of the Big Hole River's confluence with Squaw Creek appears to provide substantial recruitment.

The West Channel of the Wisdom Section was severely impacted by the low flow period of May 18 to May 26, 1992. The peak of spawning activity occurred from April 21 to 24, and densities of spawning grayling was similar in all sections. By interpolating from values given in Kratt and Smith (1977) and Wojcik (1955), we determined that the grayling fry hatched after 115.8 degree-days, or from May 2 to 4. Kratt and Smith (1977) reported that fry remain in the gravel for 3 days prior to emergence. If so, the grayling should have emerged from May 5 to 7. Upon emerging, grayling fry are relatively undeveloped and require low velocity backwater and stream margin habitats for rearing (reviewed in Armstrong 1986). The extreme low flow due to irrigation withdrawals in the McDowell Section depleted these habitats and hence only 2 YOY were captured in the West channel. An ordinarily productive side-channel of the mainstem Big Hole near the mouth of Doolittle Creek may have been similarly affected by low flows, as only 5 YOY were captured in that vicinity.

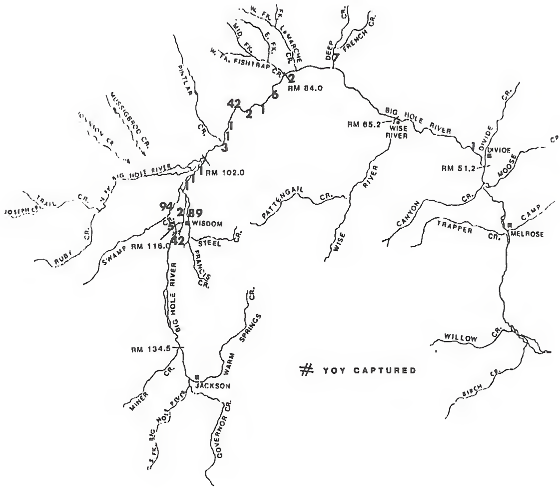


Figure 14. Map of capture sites of young-of-the-year grayling captured in Summer and Fall surveys of the Big Hole River, 1992.

Tributaries contributed considerable recruitment in 1992. In approximately 0.25 miles of Swamp Creek that was surveyed, 94 YOY grayling were captured. The East Channel of the Wisdom Section, primarily influenced by Steel Creek, provided a catch of 87 YOY grayling. Neither of these tributaries was significantly influenced by irrigation withdrawals, and recruitment was ample. YOY grayling were captured in Deep Creek (7) and near the mouth of Fishtrap Creek (2). The extent of spawning runs in these tributaries is unknown, and will be investigated in 1993.

Past catches of YOY grayling in the McDowell and Wisdom sections indicate the relative success of spawning between 1983 and present (Table 2). Extremely poor recruitment is in evidence for 1983, 1984, and 1985. The major decline in grayling density occurred from 1984 to 1986. The population stabilized near current densities after successful recruitment years in 1986 and 1989. Surveys were not conducted in 1988. Successful recruitment in 1989 is manifested in the number of Age III fish captured in 1992 surveys. In 1991, catch rates were poor in the McDowell Section, but similar to 1990 and 1992 catches in the

Wisdom Section. Low numbers of Age I grayling, the 1991 year class, were observed in the 1992 surveys. Apparently, recruitment in 1990 was restricted to the East Channel of the Wisdom Section, as the McDowell Section was affected by irrigation withdrawals, and flow was diverted from the West to the East Wisdom Channel by the gravel plug mentioned above. Moderately successful recruitment in the past 3 years suggests that the population should remain stable, and may increase under better flow conditions.

Table 2. Catch rates (catch-per-effort CPE) of Young-of-the-Year (YOY) grayling captured in the McDowell and Wisdom sections of the Big Hole River, 1983 - 1992.

Year	McDowell Section			Wisdom Section		
	# YOY	# Runs	CPE	#YOY	# Runs	CPE
1983	---	---	---	2	6	0.33
1984	---	---	---	5	7	0.71
1985	0	3	0	0	3	0
1986	145	4	38.2	---	---	---
1987	3	1	3.0	0	1	0
1988	---	---	---	---	---	---
1989	178	2	89.0	90	2	45.0
1990	58	2	29.0	98	4	24.5
1991	10	2	5.0	41	2	20.5
1992	42	2	21.0	83	4	20.8

Skaar (1989) reported extensive entrainment of YOY grayling into irrigation canals in 1988. We surveyed 2 of the same canals and captured only 5 YOY grayling, while Skaar (1989) captured over 400. In 1988, an extremely dry year, almost the entire stream flow was diverted into the ditches, which contributed to high entrainment.

Affects of Angling

Creel Census

Anglers returned 326 creel cards during the creel census period in 1992. Anglers from 34 states responded. Of the respondents, 34.7% were Montana residents. Of the non-residents, 13.8% originated in California, 11.8% from Pennsylvania, and 10.1% from Washington. Anglers from the remaining 30 states represented 28.6% of respondents. When asked if they were specifically fishing for grayling, only 23% (N=296) replied in the affirmative. The preferred method of angling was fly fishing (85.9%), followed by a combination of tackle (7.5%), and bait or lures (3.4% each).

Total angling pressure between May 15 and October 18 was estimated to be 92,817 angler hours [95% CI ± 6,667]. The majority of angling pressure was exerted by shore anglers (56,990 ± 7,333 angler-hours), while boat anglers exerted 35,827 angler hours [± 6,251]. Angling pressure was highest in the lowermost reaches (Figure 15). Reach D (Divide to Brown's Bridge) accounted for 44% of angling pressure (41,119 ± 5,391 angler-hours), while Reach C (Dickie Bridge to Divide) received 36% of the pressure (33,332 ± 5,616 angler-hours). Reach A (Jackson to Squaw Creek Bridge) accounted for the least pressure at 7% (6,709 ± 1,829 angler-hours), while slightly more pressure (12%) was exerted in Reach B (Squaw Bridge to Dickie Bridge, 11,384 ± 2,450 angler-hours).

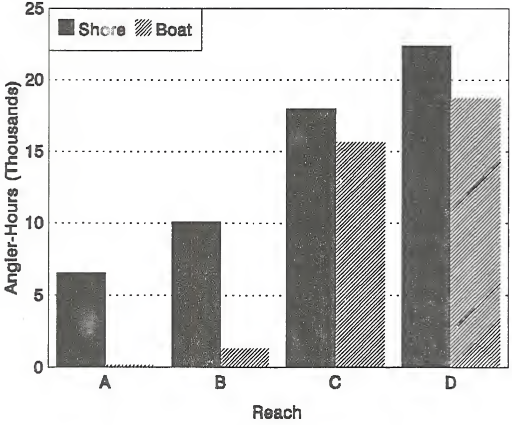


Figure 15. Total angling pressure (angler-hours) by reach for the Big Hole River creel census, 1992.

Angling pressure decreased in all reaches as the summer progressed. Total pressure in Stratum I (May 15 - July 26) comprised 54% at 50,352 angler-hours. Pressure decreased to 31,115 angler-hours in Stratum II (July 27 - September 6), and declined again to 11,350 angler-hours in Stratum III (September 7 - October 18). Catch rates (fish/hour) of grayling varied from the upper reaches to the lower reaches (Figure 16). Table 3 lists grayling catch rates by strata and reach.

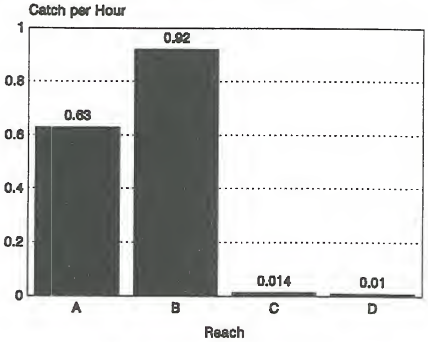


Figure 16. Catch per hour for grayling by stratum for the Big Hole River creel census, 1992.

Table 3. Catch rates (fish/hour ± 95% Confidence Interval) for grayling by section and stratum in the Big Hole River Creel Census, 1992.

Reach	STRATA			
	I 5/15-7/25	II 7/26-9/6	III 9/7-10/18	Combined
A	0.50 (±0.18)	0.37 (±0.30)	1.49 (±1.23)	0.63 (±0.24)
B	0.45 (±0.08)	1.17 (±0.62)	2.36 (±1.11)	0.92 (±0.08)
C	0.15 (±0.11)	0.12 (±0.09)	0.15 (±0.32)	0.014 (±0.06)
D	0.01	0.01	0.01	0.01

Grayling catch rates combined over all strata were not significantly different between Reaches A and B. Catch rates in Reaches A and B were significantly greater than those of both Reach C and Reach D, and grayling were caught at a significantly greater rate in Reach C than D.

In Reach A, catch rates of grayling were not significantly different from Stratum I to II, but increased significantly by Stratum III. Grayling catch rates in Reach B increased significantly from Stratum I to II to III. Catch rates remained constant through all strata in Reaches C and D.

Catch rates of other species varied considerably between reaches. Combined mountain whitefish (Prosopium williamsoni) catch rates were not significantly different in Reaches A, B, or D, or Reaches C and D. However, whitefish were caught at a significantly greater rate in Reaches A and B than in Reach C. Mountain whitefish catch rates are listed by stratum and reach in Appendix Table A3.

Brook trout catch rates combined over all strata were not significantly different in Reaches A and B. Catch rates in both Reach A and B were significantly greater than Reaches C and D. Brook trout were caught at a significantly greater rate in the 3 upper reaches than in Reach D. Brook trout catch rates are listed by strata and reach in Appendix Table A4.

Rainbow trout catch rates combined for all strata were greatest in Reach C. Catch rates were significantly greater than in Reaches A, B, and D. Rainbow trout catch rates were significantly lower in Reach A than the other 3 reaches. Rainbow trout catch rates did not significantly differ between Reaches B and D. Catch rates for rainbow trout are listed in Appendix Table A5.

Brown trout (Salmo trutta) were caught at a significantly greater rate in Reach D than in any other. While brown trout catch rates were greater in Reach C than in A or B, they did not differ significantly between Reaches A and B. Brown trout catch rates are listed by strata and reach in Appendix Table A6.

Catch rates between species varied by reach as well. In Reach A, brook trout were caught at a greater rate than any other species, except mountain whitefish. Grayling catch rates in Reach A did not differ significantly from whitefish, but grayling were caught at a significantly greater rate than rainbow or brown trout. In reach B, grayling, brook and rainbow trout, and whitefish were caught at statistically similar rates, but catch rates of all species exceeded those of brown trout in Reach B.

In Reach C, grayling catch rates were similar to those of brook and brown trout, but less than that of whitefish. Rainbow trout were caught at a significantly greater rate than all species in Reach C. In Reach D, grayling and brook trout were caught at significantly lower rates than any other species, while catch rates of the other species were statistically equivalent in Reach D.

Hooking Wounds

The frequency of hooking wounds in grayling sampled between 1984 and 1992 illustrates that where angling pressure is lowest, exploitation of the grayling population is lowest (Table 4).

Table 4. Average percent of grayling captured that exhibited hooking wounds by reach of the Big Hole River, 1984-1992. Range of percent occurrence over sampling years is given. N_{fish} is total number of grayling sampled.

Reach	Mean % ± 95% CI	Range	N_{years}	N_{fish}
A	15.2 ± 8.3	5.6 - 43.4	9	2,454
B	31.0 ± 8.3	18.2 - 45.5	6	436
C and D	29.9 ± 8.0	0 - 47.6	6	156

The frequency of hooking wounds was significantly greater in the lower reaches than in Reach A ($p<0.05$). Grayling density is greatest in Reach A where fishing access is restricted and angling pressure is lowest; consequently, the majority of the grayling population probably sustains only minor exploitation. Although grayling densities and catch rates are low in Reaches C and D, the frequency of hooking wounds is high. Due to higher angling pressure, a greater proportion of grayling are affected by angling in those sections. While Reach B contains moderate densities of grayling, fishing accessibility and grayling catch rates are high and even under moderate angling pressure a larger proportion of grayling are handled by anglers. The observed incidence of hooking wounds indicated that mortality due to hooking is certainly not absolute, and grayling are probably capable of enduring the stresses of catch and release angling.

Hooking Mortality

To further investigate the potential impacts of angling on the grayling population, we conducted a hooking mortality experiment. We captured and held a total of 14 grayling for 48 hours on 2 separate dates. The catch was composed of 7 females, 3 males, and 4 immature grayling. They ranged from 7.6 to 12.7 inches long and averaged 10.3 inches. All were caught on fly tackle: 8 on barbless and 6 on barbed hooks.

Of the fourteen grayling captured, 10 were released after 48 hours in excellent condition (no sign of stress, quickly swam away upon release) and 2 in fair condition (slow to swim away, but maintained equilibrium well). The fate of 2 grayling is unknown, as they had escaped or been removed from the live car.

Brood Reserve and Test Plants

Big Hole River

Gametes were stripped from grayling captured in the Big Hole River during spawning surveys. Eggs from 9 females were fertilized with milt from 18 males. Eggs of one female failed to fertilize. With the addition of these parents to the brood reserve, the total founding population stands at 28 pairs, considered by Leary (1991) to be sufficient to capture the variability in genotypes of wild Big Hole River grayling when crossed. The various year classes will be reared at the FTC until 1995, when a modified diallele cross will be performed to create a reserve stock with genetic variability equivalent to the wild stock. This is necessary to prevent swamping of the wild genotypes should supplementation with reserve grayling be employed.

Axolotl Lake Reserve

We also collected gametes from the Axolotl Lake reserve stock. A total of 299 grayling was captured in fyke nets during May, 1992. Ripe females were captured between May 13 and 16, when mid-lake temperatures ranged between daily averages of 48.7 to 49.4 F. Maximum daily temperatures ranged from 48.1 to 50.0 F. Female grayling were ripe three weeks later, but for the same duration and at nearly the same temperatures as the Big Hole grayling. No grayling ascended the stream to spawn.

Fifty-five female grayling were spawned with 110 males on May 15 and 16. These fish will be reared at the FTC and will represent the 1988 year class in the modified diallele cross. An additional 28 female grayling were spawned on 56 males by USFWS ENFH staff to determine the effects of water hardening the eggs in various concentrations of betadine disinfectant solutions. They observed 100% mortality at all concentrations (Dan Brown pers. comm.). Fifty-eight grayling were sacrificed for disease testing at the MDFWP Fish Health Laboratory.

Based on mark-recapture ratios the grayling population in Axolotl Lake was estimated to be 810 [± 119]. Approximately 2,800 grayling averaging approximately 5.0 inches were planted in 1988 (Kaya 1990). Their average length in 1990 was 10.5 inches, and was 12.4 and 13.1 inches in 1991 and 1992, respectively.

Gallatin River Experimental Reintroduction

A total of 148 grayling were reported as captured in the Gallatin River by 58 anglers. One grayling was captured in the East Gallatin River 34.2 miles above its confluence with the Gallatin River (Figure 5).

The river mile (distance measured upstream from mouth) of each capture site was pooled with others, by month, to indicate the relative distance the grayling had moved since planting. Mean river miles (RM) of capture site, by month, are listed in Table 5.

Table 5. Mean river mile of capture sites of Arctic grayling reported captured by anglers in the Gallatin River, 1992.

Month	Area of Mean Capture Site	Mean River Mile	Range	Number Captured
7/1/92	[Plant]	87.7	88.0-87.3	[5400]
7/92	Porcupine Creek	73.3	87.0-54.0	13
8/92	Squaw Creek	52.6	86.0-33.9	63
9/92	Shedd's Bridge	34.0	59.6-26.6	55
10/92	Cameron Bridge*	26.6	26.6	2
11/92	Asbestos Creek	64.8	64.8	1

* One grayling was captured in October by an angler 34.2 miles upstream from the mouth of the Gallatin River in the East Gallatin River near Bozeman.

It appears that the planted grayling moved as a group. Within July, shortly after planting, 13 grayling were captured by anglers from the planting sites to as far as 33 miles below the planting sites. In August, grayling were still being caught in the vicinity of planting, but they were caught as far as 54.1 miles downstream. By September, capture sites were concentrated further downstream with a mean of RM 34, and primarily north of the mouth of Gallatin Canyon. Only 3 grayling were reported as captured in October, 2 at RM 26.6, and one grayling caught in the East Gallatin River, 122 miles from the plant sites. A single grayling was reported to be caught in November, at RM 64.8.

Reasons for the mass movement are as yet undetermined. It is likely that the grayling were searching for more suitable habitats. Grayling in the Big Hole River exhibit extensive movements, and the planted graylings' movements may simply reflect a natural tendency to migrate. Further monitoring of their movements and survival will be conducted in 1993.

Only 3 grayling were observed during electrofishing surveys. On October 5, in the Gateway to Axtell survey (RM 39.0 - 36.8), 2 grayling were captured, 9.3 and 9.0 inches long. Their mean length at planting was 5.9 inches. Apparently, the grayling grew between 1 and 5 inches post-planting. Growth indicates that the planted grayling probably were not unduly stressed by planting. A third grayling was observed, but not captured, in that reach. No grayling were observed in the 3 upstream sections we electrofished.

Big Hole River Experimental Plant

Of the 214 stocked in the Big Hole River only 1 documented planted grayling was captured in fall electrofishing surveys. It was captured on September 21 at Sportsman's Park, approximately 7 miles downstream from the planting site. It was 8.2 inches long and weighed 0.22 lbs. It is possible that others were captured but not recognized due to loss of VI tag. A coded wire tag detector was not available, but will be used in future surveys in 1993.

DISCUSSION

Discharge and Water Temperature

Water year 1992 was among the driest in the past seven years. Low flows in May affected recruitment in the mainstem Big Hole River in the McDowell and West Wisdom channels. Under more normal flow regimes, it is unlikely that recruitment would be influenced by low flows. Recruitment in tributary streams was protected by ample flows through the critical post-emergence period. Low flows in August and September were similar to those in the last several years. Adult grayling survival was probably affected by low late summer flows in 1992. Because mature grayling exhibit migratory tendencies, they may be able to escape extremely low flow conditions to some extent. Grayling movements are being investigated, and will be reported later.

Cooperation with water-users was beneficial in maintaining flows during the post-emergence period. Additional flow supplementation through water conservation practices is being pursued.

Water temperatures in the Big Hole River peaked at the Christiansen Ranch station. Considerable gains in temperature were observed between the upper river (Peterson Bridge station) and the Wisdom area. Groundwater accretions and tributaries maintained relatively equivalent temperatures between the Wisdom and Buffalo Ranch stations. The broad, shallow channel from the Buffalo Ranch to the Christiansen area evidently contributes to the warming trend between those stations, but is buffered somewhat by the North Fork of the Big Hole River.

The peak temperature recorded at the Christiansen station approached the CTM cited in Feldmuth and Eriksen (1978). However, their study was based on grayling from ODell Lake, which were shown to be genetically dissimilar and probably are not exposed to the same temperature regime as Big Hole River grayling (Leary, MDFWP Files). A thermal bioassay should be conducted to determine CTMs for Big Hole grayling to identify the range of temperatures they can physiologically withstand. The Big Hole grayling may have adapted, over time, to the current thermal conditions. However, it is possible that climatic change may have diminished the suitability of the Big Hole River for grayling.

Population Status

The Big Hole basin has been in a drought cycle for the last 7 years. Consequently, the density of all fish species in the upper Big Hole River sections has declined. Estimated population densities with respect to mean May to August flows are listed in Table 6 (Modified from Hunter, MDFWP files). The relationship of habitat volume and discharge is well documented and accepted by aquatic biologists. Average discharge at the USGS Melrose gage from May through September 1985 - 1991 ranged as low as 31% of the 50-year average flows. The lowest recorded mean monthly flow was 17% of the 50-year norm in August, 1988. The persistent drought conditions in the Big Hole basin appear to have drastically affected all resident species of fish by decreasing habitat availability. It is likely, therefore, that the drought, a density independent factor, is a major influence limiting the grayling population as well as other fish species in the Big Hole River.

Table 6. Estimated densities (number per mile) of Age I+ grayling, Age II+ brook trout, and Age I+ rainbow trout in the McDowell, Wisdom, and combined (McWisdom) sections of the Big Hole River, and mean percent of 50-year average May through September discharge (cfs) measured at the USGS Melrose gaging station, 1978 - 1991. Modified from Hunter 1992 (MDFWP files).

Section	Year	Species (#/mile)			Mean % of 50-yr flow
		Grayling	Brook	Rainbow	
McDowell	1978	49	109	0	---
Wisdom	1983	111	234	11	---
Wisdom	1986	68	274	11	---
McDowell	1985	39	208	26	58
Wisdom	1985	33	331	5	58
McDowell	1986	49	211	27	86
McWisdom	1987	30	82	3	35
----	1988	---	---	---	31
McWisdom	1989	24	62	3	54
McWisdom	1990	35	65	6	54
McWisdom	1991	35	---	---	67

Estimating the density of grayling in the Big Hole River is difficult. Because of low densities and extensive movements between mark and recapture runs, estimates may be biased. Consistency in estimates between years is uncertain due to changes occurring in channel morphometry and low flows during sampling. Table 7 lists population estimates in the McDowell, Wisdom, and McDowell and Wisdom sections combined (McWisdom) based on different estimators.

Based on the least biased estimators, the population severely declined in the Wisdom vicinity between 1983 and 1985, presumably after high run-off flows limited recruitment in 1983 and 1984 (R. Oswald pers. comm.). After the onset of drought in 1985 the population declined to approximately 27 per mile by 1987. This figure is extremely speculative, because it was derived from electrofishing efficiency ratios documented in 1989. By 1989, after 4 consecutive years of drought, the population stabilized at approximately 30 per mile, where it has remained to date.

Table 7. Estimated Age I+ grayling population densities in the Wisdom, McDowell, and McWisdom (McDowell-Wisdom combined) survey sections of the Big Hole River, 1978 to 1992, calculated by electrofishing efficiencies (E), or pooled (P) estimators.

Year	Est.	Section (Length in miles)		
		Wisdom (4.9)	McDowell (4.9)	McWisdom (9.9)
1978			69[a]	
1989	P E	118 ± 60 111 ± 50[b]		
1989	P E	69 ± 29 68 ± 29[b]		
1985	P	33 ± 23	39 ± 31	44 ± 29[b]
1985	P		49 ± 27	
1987	E		22[c]	
1988[d]				
1989	P E	17 ± 10 19 ± 11	22 ± 18	25 ± 14 30 ± 18[b]
1990	P E	41 ± 12 40 ± 11	39 ± 21 33 ± 16	36 ± 11 35 ± 10[b]
1991	P E	27 ± 16 29 ± 18[b]	e	36 ± 24 35 ± 34
1992	P E	37 ± 23 31 ± 16[b]	e	21 ± 13 19 ± 10

[a] From Liknes 1981.
[b] Indicates least biased estimate
[c] Based on 1989 efficiencies, no recapture run completed due to low flows.
[d] No survey, low flows.
e Estimate not available, no recaptures.

Bias in estimating populations with mark/recapture ratios may occur due to low sample sizes, low recapture rates, or to movements out of the sample section. Bias may also result because electrofishing sampling efficiency varies with size of the fish being sampled (Robson and Regier 1964, Vincent 1971). The added bias of combining heterogeneous samples between sections reduces precision of estimates. For example, in 1991, 17 graying were captured in the McDowell Section marking run, while of 16 grayling that were caught in the second run, none were recaptures. By adding these 33 fish to the Wisdom section, and doubling the section length, the estimate was biased upward. However, in a year such as 1990, when recapture rates were adequate in both sections, a less biased estimate was derived by combining the sections, thereby increasing the sample size and accounting for some movement between sections.

Problems in quantifying the grayling population may be solved with a large-scale population estimate covering a large expanse of river, as recommended by Oswald (1990). Our attempt to conduct a large-scale survey in 1992 was impeded by low flows and sampling inefficiency.

While the precision of estimates may be in question, they certainly provide an index for the grayling population. The decline observed between 1983 and 1989 appeared to be a result of a combination of extremely high run-off years followed by severe drought. The grayling population stabilized between 1989 and present, presumably at levels determined by persistent drought conditions.

The future of the population is uncertain. The 1992 spawning run appeared to provide good to moderate recruitment. An abundance of Age III+ spawners provided the strongest run since 1989. The 1989 year class provided a majority of the spawners and appeared to survive low summer flows in moderate numbers, and their survival through winter will affect the 1993 spawning run. The Age II class was not well represented in the 1992 spawning run, but was present in moderate numbers in fall estimates. Approximately 80% of Age II grayling captured during the spawning run were mature, the majority of which were males. With the abundance of older age classes, a large portion of female Age II grayling may not have matured to spawn and may have been absent from spawning surveys. Recruitment in 1990 was limited, and low numbers of yearling grayling were apparent in the length-frequency distribution from fall surveys.

The population should remain stable over the next few years if summer and winter survival of Age III+ fish is sufficient. The 1993 spawning run will depend on the 1989 - 1990 cohorts. Because of low numbers of the 1991 year class, numbers of Age II spawners will likely be low in 1993. The 1992 year class should provide relief in 1994, as Age III+ spawners will be limited. In order for the grayling population to recover to pre-1985 abundance, several wet years with gradual run-off and ample mid-summer flows will be required.

Affects of Angling

Arctic grayling in the Big Hole River are easily caught by anglers. Catch rates in the upper river, above Dickie Bridge, averaged between 0.37 and 2.36 fish/hour, which are relatively high catch rates. Grayling were documented to have been caught by anglers in disproportionately high ratios to their abundance (Kaya 1990). Catch-and-release only regulations were initiated in 1988 to protect the declining population, and remain in effect.

To assess the potential effects of angling on the grayling population, we combined information gathered from creel census, hooking wound frequency, and hooking mortality. Preliminary results indicate that angling plays a minor role, if any, in limiting the Big Hole grayling population. The greatest densities of grayling are found in the vicinity of Wisdom, with moderate densities found in the reach between Squaw and Dickie bridges. Reach A, from Jackson to Squaw Bridge, received only 7% of the fishing pressure, while Reach B received 12%. Eighty percent of angling pressure was exerted in Reaches C and D, where grayling densities are low. Limited access in Reach A apparently restricts access by anglers to the "core" grayling population in the Wisdom area, and thereby protects them from over-exploitation. Angler access to Reach B is readily available, and yet angling pressure was moderate. The frequency of hooking wounds on grayling in Reach A was approximately half of that documented in Reach B and in Reaches C and D, which again emphasizes the low exploitation rate of grayling in Reach A. Although density of grayling in Reach B is moderate, hooking wound frequency averaged nearly 30%. This portion of the population receives higher angling pressure and may be exploited to a greater extent.

Mortality due to hooking injury warrants further investigation. Our results are inconclusive due to low sample size. We did not document any short-term mortality, but previous studies reported hooking mortality rates from 0.5 to 2.7% (Nuhfer 1990) and 8.7 to 11.7% (Falk and Gilman 1975) for grayling.

Brood Reserve and Experimental Plants

Gametes collected in 1992 fulfilled the required number of "founding parents" recommended by Leary (1992) to sufficiently capture the variability of the wild Big Hole River grayling genotypes. The gametes collected at Axolotl Lakes will represent the 1988 year class in the reserve stock. The 1992 collections will be reared at FTC with the other year classes until 1995 when all year classes will be crossed to provide a genetically variable reserve stock suitable for supplementation of the Big Hole population or for reintroductions to other streams.

The fluvial grayling stocked into Axolotl Lake exhibited a lack of adaptation to the lacustrine environment. They failed to ascend the inlet stream to spawn and swam around the shallows of the lake in schools. This further illustrates the behavioral adaptation of Big Hole River grayling to living in a fluvial environment.

Preliminary information from the test plants in the Gallatin and Big Hole rivers indicated that at least a portion of the plant survived and grew into fall. Movements of grayling planted into the Gallatin River indicated a concerted downstream migration. A planted grayling captured in the East Gallatin River, approximately 120 miles from the plant site, would suggest a migration oriented by a factor other than an inability to maintain position in a flowing environment. Monitoring of both plants will continue in 1993. A single planted grayling was recaptured in the Big Hole River approximately 7 miles below the planting site.

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APPENDIX

Table A1. Count dates, starting locations, and count times for the Big Hole River Creel Census, 1992.

Date	Start Location	Count 1 Start Time	Count 2 Start Time
June 22	Browns	800	1300
June 26	Jackson	700	1300
June 30	Jackson	900	1300
July 6	Browns	600	1600
July 19	Browns	600	1300
July 23	Jackson	700	1600
July 25	Browns	600	1300
July 29	Jackson	800	1600
August 2	Browns	600	1300
August 5	Jackson	800	1500
August 12	Jackson	600	1300
August 16	Browns	800	1600
August 20	Jackson	900	1600
September 6	Jackson	700	1300
September 9	Jackson	700	1300
September 13	Jackson	700	1300
September 14	Browns	700	1300
September 13	Jackson	700	1500
September 26	Jackson	800	1300
October 14	Browns	900	1400

Table A2. Procedure for conducting angler counts for the Big Hole River Creel Census, 1992.

I. Introduction

A. The object of creel counts is to count as many anglers as possible within a given time period, which can be expanded to estimate overall fishing pressure.

B. We will count anglers, anglers per boat, boats, anglers per car, and cars, depending on the section.

C. The river is divided into four sections:
(A) Miner Lake Bridge at Jackson to Squaw Bridge,
(B) Squaw Bridge to Dickie Bridge,
(C) Dickie Bridge to Divide Bridge, and
(D) Divide Bridge to Brown's Bridge.

D. Each "creel count day" is randomly assigned a starting point (Jackson or Brown's Bridge) and two start times. The morning count begins at the specified location at the specified time. An afternoon count then, begins at the alternate site at the specified time. For example, the morning count is to begin at 8:00 a.m at Brown's, and the afternoon count begins at 1:00pm at Jackson.

E. The count should take less than 1 hour per section, and should be done consecutively, without pause according to the route listed below. At the end of the count or if anglers are standing around, make an effort to contact them to ask: how many anglers in their party?, if they were fishing from a boat, how many boats and anglers per boat? if arrived in a car, how many fisherman arrived in their car?, and request that they fill out a creel card. Report on Party Interview Sheet.

F. For sections A and B count vehicles only if it is obviously associated with anglers, and make note on the count sheet. At Fishing Access Sites, only count vehicles if they are known to be fishing, otherwise don't count them.

G. In sections B,C,D, count boats and anglers per boat, as well as empty boat trailers at Access points listed on count sheets.

H. Take a supply of envelopes and creel cards and replenish creel stations as needed. Put about 1/2 as many envelopes as creel cards in boxes, and remove completed cards from locked box.

Table A2. Continued

I. When counting from highway, drive slowly and carefully, making use of any available turnouts to look for anglers. Take binoculars.

II. COUNT ROUTE -(Reverse if starting from Jackson)

Section D.

Brown's Bridge- look up and downstream for anglers, boats, etc., count cars, trailers too. If at end of count, interview for party information, or proceed to Melrose.

Melrose (Salmonfly FAS)-count anglers up and down river, count trailers, boats, cars, etc. and make angler contacts, or proceed to Maidenrock.

Maidenrock- count up and downriver, count cars, boats trailers, and make contacts, or proceed to Divide.

Divide FAS- count anglers BELOW bridge on river all the way through campground, count boats, trailers, and obvious angler cars only at upper lot, make contacts if have time, or proceed to Section C.

Section C.

Divide Bridge to Butte H20 Bridge- Take back road by Butte water intake and count anglers and boats, proceed up canyon to Dewey .

Canyon to Dewey-Drive with caution, using turnouts to look down to river to count boats, and anglers, at Dewey FAS count cars and trailers, make contacts, or proceed to Jerry Cr.

Dewey to Jerry Cr-Drive carefully, counting anglers and boats visible from highway, count cars only if obviously associated with anglers. At Jerry Creek FAS count cars and trailers as well as wading anglers up and downstream of bridge. Proceed to Johnson Cr. Road.

Johnson Cr. Road-Drive through Wise River, count anglers visible from highway (probably difficult except at Foxley's) and drive down Johnson Creek Road as far as necessary to count anglers and boats downstream from Dickie Bridge only. Proceed to section B.

Table A2. Continued

Section B.

Dickie to Bryant Cr.- Drive up Bryant Creek Road as far as necessary to count anglers, and boats (put in comments on old data sheets), proceed to Eastbank, careful not to count anglers twice.

Eastbank FAS- Count anglers, obvious angler cars, trailers, look up and downstream if necessary, proceed toward Sportsmans.

Eastbank to Sportsmans- Along highway carefully count angler, boats, and obvious angler cars, stop at Sportsman's Park.

Sportsmans Park- Along campground, count ONLY anglers along bank (too many campers to count cars), but at upper pool count OBVIOUS angler cars only. Proceed to Fishtrap.

Sportsmans to Fishtrap-Carefully count anglers and boats/ boat anglers as you drive along, at Fishtrap FAS count only anglers and obvious angler cars. Proceed to Sawlog.

Fishtrap - Sawlog- Carefully count anglers from highway, if you can see sawlog from hill above count there, if not take drive through Sawlog access, count anglers and obvious angler cars, proceed to Squaw Bridge.

Sawlog - Squaw-count anglers carefully from highway, and obvious angler cars, proceed to Section A.

Section A.

Squaw - N. Fk. Road- Drive up North Fork Road until you can no longer see river (just past big bend) and count anglers and their cars, proceed back to bridge.

Christiansens Bend to Pintler- Drive up to where river meets highway again, and begin counting anglers and their cars all the way up to and including the Pintler access. Proceed to Cemetary area.

Cemetery to Wisdom Bridge- Since you can't see river much until the cemetery, begin counting there as long as channels are visible and then go to the Wisdom Bridge, where you should count anglers and their cars up and downstream, proceed to bridges.

Table A2. Continued

Bridges- At each bridge crossing, look for anglers and their cars, includes bridges at: Clemow Lane (McDowell put-in), Two Curves (next br. So. of Clemow), Jorgenson, Peterson, and Miner Lake (So. of Jackson). That ends the count. Wait until next count time, or go home!

Table A3. Catch rates (fish/hour ± 95% Confidence Interval) for mountain whitefish by section and stratum in the Big Hole River Creel Census, 1992.

Reach	STRATA			
	I 5/15-7/25	II 7/26-9/6	III 9/7-10/18	Combined
A	0.84 (±0.07)	1.05 (±0.21)	0.89 (±0.24)	0.91 (±0.05)
B	0.72 (±0.02)	1.10 (±0.13)	0.73 (±0.06)	0.84 (±0.02)
C	0.31 (±0.01)	0.73 (±0.02)	0.0	0.51 (±0.01)
D	0.39 (±0.01)	1.10 (±0.03)	0.49 (±0.03)	0.71 (±0.01)

Table A4. Catch rates (fish/hour ± 95% Confidence Interval) for brook trout by section and stratum in the Big Hole River Creel Census, 1992.

Reach	STRATA			
	I 5/15-7/25	II 7/26-9/6	III 9/7-10/18	Combined
A	1.33 (±0.13)	1.49 (±0.02)	0.58 (±0.07)	1.26 (±0.06)
B	0.54 (±0.02)	1.25 (±0.25)	0.77 (±0.08)	0.79 (±0.03)
C	0.17 (±0.00)	0.05 (±0.00)	0.0	0.10 (±0.00)
D	0.01 (±0.00)	0	0	0.004 (±0.000)

Table A5. Catch rates (fish/hour ± 95% Confidence Interval) for rainbow trout by section and stratum in the Big Hole River Creel Census, 1992.

Reach	STRATA			
	I 5/15-7/25	II 7/26-9/6	III 9/7-10/18	Combined
A	0.21 (±0.01)	0.14 (±0.01)	0.05 (±0.01)	0.16 (±0.00)
B	0.38 (±0.01)	1.65 (±0.01)	0.50 (±0.12)	0.79 (±0.01)
C	1.26 (±0.05)	0.95 (±0.02)	1.85 (±0.31)	1.13 (±0.02)
D	0.90 (±0.03)	0.54 (±0.01)	0.98 (±0.05)	0.76 (±0.01)

Table A6. Catch rates (fish/hour ± 95% Confidence Interval) for brown trout by section and stratum in the Big Hole River Creel Census, 1992.

Reach	STRATA			
	I 5/15-7/25	II 7/26-9/6	III 9/7-10/18	Combined
A	0.05 (±0.01)	0	0	0.02 (±0.05)
B	0.01 (±0.00)	0.06 (±0.01)	0.09 (±0.01)	0.08 (±0.00)
C	0.31 (±0.01)	0.17 (±0.00)	0.31 (±0.08)	0.24 (±0.00)
D	0.92 (±0.11)	0.75 (±0.01)	0.92 (±0.14)	0.85 (±0.01)